Influence of axial features of abdominal aortic aneurysms on the expansion rate: a computational case study using 3D finite elements

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ABSTRACT

Abdominal aortic aneurysms (AAAs) often remain asymptomatic until rupture, an event with high mortality rate. Clinical capabilities for predicting accurately the risk of rupture remain wanting, and clinical interventions continue to be based primarily on the maximum diameter or expansion rate of the lesion. Additionally, the majority of available clinical and experimental data focuses solely on radial changes and AAA maximum diameter, whereas changes in length, microstructure in axial direction, and axial growth rate have not been investigated. It is possible that this could lead to the incorrect conclusion that aneurysm is stable in case the maximum diameter does not change, while an aneurysm could still grow in axial direction. Therefore, in this contribution we study the importance of aneurysm length and axial growth rate on the rate of radial AAA expansion, and possibly rupture.

We implemented the constrained mixture growth and remodeling model presented in [1] into the finite element analysis program (FEAP). Implementation of the model entailed several challenges. Incompressibility of material was enforced by using penalty functions, and the Augmented Lagrange method. Unlike the first attempt of using full 3D finite elements for describing growth of aneurysms [2], we used a mixed formulation for describing strain energy of fibers (i.e., collagen and smooth muscle cells), as was suggested in several investigations, e.g., [3].

To model aneurysm, we degraded elastin similarly to [4]. We modified the elastin degradation function to enable it to capture aneurysms of different lengths and axial growth rates. However, the function remains solely time-dependent. Future studies should seek to consider degradation of elastin based on a distribution of elastase diffusing from thrombus, as in [5].

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